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CONSIDERATIONS

ON THE PROPOSED COMMUNICATION BY A

NAVIGABLE CANAL,

BETWEEN THE TOWN OF SHEFFIELD

AND THE

PEAK FOREST CANAL;

WITH

REMARKS AND CALCULATIONS

TENDING TO PROVE THE SUPERIORITY OF

AN EDGE-RAILWAY

FOR PASSING OVER A MOUNTAINOUS DISTRICT,

And a comparative account of the several practicable lines which have hitherto been pointed out.

BY HENRY SANDERSON,

LAND SURVEYOR.

Sheffield:

PRINTED BY G. RIDGE, 3, KING-STREET.

1826.

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PREFACE.

THE proposed communication between Sheffield and Manchester by means of a Junction Canal, has been so long under discussion that one would suppose the public had by this time arrived at a tolerably just conclusion concerning the probable success of such an undertaking, and that the best line for the purpose had been clearly and accurately ascertained. But this, I believe, is far from being the case; and I am also persuaded, that if the relative advantages and disadvantages of canals and railways were fairly and intelligibly stated, the idea of carrying a *canal* across the *Grand Ridge*, which in any direction must be attended with an enormous expense, would not be so favorably received as it has hitherto been.

Under this impression I am induced to publish my own thoughts on the subject, in the hope that I shall be able to impart some useful information, which, if I really possess it, has been gained by bestowing on the subject a more than ordinary degree of attention.

In doing this it is far from being my wish to give offence to those gentlemen who have projected the intended "Sheffield and Manchester Junction Canal." They can have no desire to mislead the public, but may possibly themselves entertain erroneous ideas of their own project; and if, by comparing their plan with others which appear more generally advantageous, they should become convinced of its ineligibility and discontinue to support it, my labours will have proved more useful than I dare venture to anticipate. The spirited manner in which the business has been commenced, indicates a degree of confidence on the part of the projectors which cannot be easily shaken; and yet, if the speculation is likely to turn out unprofitable to the subscribers generally, the sooner it is abandoned the better. If the contrary prospect can be clearly exhibited to the public, nothing which I have written can do it any injury.

I consider the execution of expensive but unprofitable projects to be a misfortune, rather than any advantage, to the country in which they are adopted. There is undoubtedly produced by all works of great magnitude, an extraordinary demand for labour; but this demand is only temporary; and the future effect will be, a diminution of the quantity of permanent employment, whenever the capital of the country is absorbed in unprofitable schemes. Besides this, another bad consequence must ensue; the disappointment of high-raised hopes and sanguine expectations will assuredly act as a bar to future projects of a similar nature, however desirable or promising they may be.

I do not, therefore, wish that a canal should be made at *any* expense, or in *any* direction, but desire rather that the *most* beneficial line should be discovered and acted upon; or, if a canal westwards do not appear, upon close investigation, likely to pay sufficient interest to the subscribers, that a railway should be adopted as its substitute. Such a mode of conveyance as this, keeping near to the Derbyshire limestone, cannot fail to pay an ample dividend. It may be relied upon with certainty, and would be brought into operation in one third of the time required for the completion of the proposed canal.

In making my calculations of the friction upon an edge-railway, and the power of locomotive-steam-engines, as well as the friction of ropes used on fixed-engine planes, I am guided by the valuable experiments detailed in a 'Treatise upon Railroads' published last year; the author of which is Mr. Nicholas Wood, viewer of the Killingworth and other collieries near Newcastle-upon-Tyne.

At the Killingworth colliery there is an edge-railway four miles in length upon which the coals are conveyed to the river; and these experiments were made with the carriages and engines in common use upon that railway; they cannot, therefore, involve any such errors as frequently arise from the use of models upon a small scale.

I have endeavoured in the following pages to render my calculations as intelligible as possible; for I do not see the utility of wrapping up the most simple rules in algebraic *formulæ* which but few can understand. It is my wish to place the subject in a clear point of view before the public generally; and if I have failed in this object, I hope that some one, more qualified for the purpose, will take the trouble to improve upon what I have herein advanced.

Porto Bello, Sheffield,
April, 1826.

CONSIDERATIONS, &c.

I CANNOT commence the subject of these pages better than by giving the reader a brief description of the several projects for effecting the desired communication by canal, which have from time to time been taken into consideration.

Thirteen years ago, Mr. Chapman, of Newcastle-upon-Tyne, made a report in which he pointed out the practicability of forming a branch from Sheffield to unite with the then-proposed High Peak Junction Canal a little below Padley Mill on the Burbage Brook. He proposed to ascend the valley of the Sheaf to the foot of the mountainous ridge at Strawberry Lea; and to pass under the East Moor by a tunnel 2¾ miles in length; from the west end of which to the point of junction, Mr. Chapman said, would be only a quarter of a mile further. The following is an extract from his report.

"This Line would ascend the vale of the Sheaf by a rise of nearly 440 feet in six miles and 70 chains, to where it would enter by a tunnel the narrowest ridge on the mountains, between the Derwent and any suitable point on the eastern side, on the same level. The length of the tunnel would be 2¾ miles to where it would terminate on the western side near Padley Mill, on Burbage Brook, which it would pass by a culvert; and by a short canal of a quarter of a mile in length would come on the same level to where the projected canal from the Peak Forest might join it, without any deviation from its proper course."

Mr. Chapman was perhaps not aware that the level of the proposed High Peak Junction Canal, at the point where his line would join it, was 140 feet lower than the level of his proposed tunnel; and the distance of that point from the end of the tunnel being only a quarter of a mile, the inclination would be somewhat steeper than 1 in 9. But as no inclination exceeding 1 in 30 will admit of locks of a reasonable depth, it is obvious that the junction could not have been effected in the line pointed out by that gentleman. Another objection to this plan, if it were practicable, would be, the necessity of making reservoirs above the level of the tunnel, to supply it with water. Both of these objections, however, may be removed by making the tunnel on a lower level, and joining the High Peak Junction line two miles further up the valley.

From this time (1813,) the idea of a junction canal remained dormant till the spring of 1824, when it was revived in a different shape; forming part of a much more extensive and consequently a much less feasible project. This was the proposed "Grand Commercial Canal," intended to unite the Chesterfield and Peak Forest, with the Sheffield and Cromford Canals. Mr. Joseph Hazlehurst, of Unston, announced himself to be the engineer, and published an eye-sketch consisting of a few straight lines at the head of an ill-digested report and estimate. The first report, or prospectus, was superseded by another publication which Mr. Hazlehurst issued soon afterwards, entitled "the Second Report upon the proposed Grand Commercial Canal," containing a more particular eye-sketch of his line, estimates exhibited in detail, and much valuable miscellaneous information; though there appears to be a great degree of amplification in his statements of the revenue to arise from the project, and the local as well as general advantages which it would present.

With regard to that part of Mr. Hazlehurst's plan which would have formed the communication between Sheffield and Manchester, it should be observed that the line of the proposed High Peak Junction Canal was adopted by him as far as Grindleford

Bridge; whence by means of a tunnel to Barlow Woods, he contrived to carry the line close to his colliery at Unston, before it appeared convenient to turn towards Sheffield. But we are assured this arrangement was not caused by selfish considerations.

In opposition to Mr. Hazlehurst, there came forward Mr. James Dean, formerly of Tavistock-street, Covent Garden, but now of No. 90, High Holborn; a person who is known chiefly in this neighbourhood as the agent of a lady residing at Dronfield.

Having taken the necessary levels between the four canals and formed his plan, Mr. Dean caused a very inaccurate yet highly finished sketch of the country to be drawn by Mr. John Thompson, of Wellington-street, Strand; upon which his line was delineated, and thus was exhibited at two public meetings held in Sheffield.

The pictorial style, however, in which this map is drawn, though very suitable for the representation of a nobleman's park, is not at all proper for the purpose to which Mr. Dean has applied it; because it prevents the spectator from exercising his judgment on the merits of the line, by exciting his admiration of the beautiful shades and colours in which it is enveloped. But let the subject of a map be what it may, a considerable degree of accuracy is undoubtedly necessary to warrant so much trouble in the colouring and finishing; and as an instance of the inaccuracy of this map with regard to the situation of places, I will mention that the Sheffield Canal is represented passing between Attercliff and the River Dun; while it is well known to all its inhabitants, that their village stands between the river and the canal. In fact, to those who know the country, so many inaccuracies present themselves in Mr. Dean's map, that it has every appearance of being a *sketch* grounded upon the old county survey published sixty years ago. There is certainly no harm in making sketches from old maps, however erroneous they may be in the detail, when there is not time enough to make new and accurate surveys; but it is injudicious, by enlarging the scale, to render the errors more conspicuous; and still more so to waste time in ornamenting productions of so little value.

In forming that part of his plan which would effect a junction of the Sheffield and Peak Forest Canals, Mr. Dean did not think it advisable to follow exactly the line laid down by the late Mr. Rennie; though he accompanies it at no great distance from Chapel-Milton to Padley. Mr. Dean commences his new line at Bugsworth, while

Mr. Rennie taking advantage of the intended extension of the Peak Forest Canal, began the line of the proposed High Peak Junction Canal near Chapel Milton. Mr. Rennie proposed to pass the Cowburn Ridge by a tunnel of two miles and three quarters, at the height of 150 feet above the level of the line at its commencement; but Mr. Dean proposes to lengthen the tunnel very considerably, by passing the ridge upon a level 100 feet lower. Instead of descending with Mr. Rennie's line along the vale of the Derwent, Mr. Dean keeps on the hill-side above Hathersage; and after tunnelling under the East Moor to Smeecliff Wood, carries the same level by Millthorp, Cowley, Stubley, Greenhill, and Norton, to near the Manor Farm-house in Sheffield Park; from whence he recommends the adoption of a railway and inclined plane, which would be about a mile and a half long and 449 feet in perpendicular height; or if a railway should be thought objectionable, proposes to pass down the vale of the Sheaf, from Greenhill, by lockage.

However eligible a plan Mr. Dean's or Mr. Hazlehurst's might be for a *fourfold* union, it is very evident that the town of Sheffield would not derive that advantage from it which would accrue from a distinct and direct union of its canal with that of the

Peak Forest. On this account the proposed Grand Commercial Canal did not meet with that support here which its projectors had anticipated. Another great drawback upon its utility, and the probability of its being carried into execution, is the Peak Forest and Cromford Railway designed by Josias Jessop, Esq. of Butterley Hall; for which an act of parliament was obtained in the last session, and which is now in rapid progress.

In November, 1824, another plan was set on foot, for a canal from Sheffield to the Peak Forest Canal at Hyde-Lane, by way of Wortley, Penistone, Woodhead, and Mottram; the direction of which for some distânce from Sheffield is nearly due North, being up the valley of the Dun. The supporters of this plan employed Thomas Telford, Esq. the eminent civil-engineer, at a great expense, to survey the country, lay down a line with accuracy, and make an estimate of the sum required for its execution.

As Mr. Telford's reputation stands so high in works of this nature, I shall perhaps be excused for inserting here a copy of his report; particularly as I wish to offer some remarks upon it; which, for the sake of convenient reference, shall be given in the shape of notes.

Mr. Telford's Report of the proposed Sheffield and Manchester Junction Canal.

" In consequence of your instructions, I proceeded to examine the country lying between the town of Sheffield, and the western end of the Peak Forest Canal; with a view to ascertain the practicability of forming a water communication in the most direct line between Sheffield and Manchester*.

"The River Dun which takes its rise near the junction of the counties of York, Derby, and Chester, upon the summit of the high ridge of mountains, which separate in a longitudinal direction for a great distance, the waters that flow to the east and west seas, passes through the town of Sheffield and falls into the Humber†.

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* It has been said that Mr. Telford considered the valleys of the Dun and Etherow to form the most direct practicable line by which a water communication could be effected with the Peak Forest Canal. But the words which that gentleman here uses, clearly shew that his attention was *confined* to the *western* end of that canal; and every engineer, however eminent or respectable, must attend to his instructions; particularly if he consider it important that he should be properly remunerated for his trouble. Mr. Telford is not an obscure engineer who is seeking for reputation; he has already acquired it, and has too much profitable business on his hands to allow of his surveying any lines but those which are pointed out to him. Had his instructions been " *to examine the country between the town of Sheffield and the Peak Forest Canal* " without mentioning either end, Mr. Telford would, no doubt, in due time, have informed his employers, that the shortest and most direct line would join the Peak Forest Canal at its *eastern* end.

† It is generally understood, that the Dun falls into the Ouse; but perhaps geographical accuracy does not " fall under the principle of civil engineering."

"At a short distance from this source of the Dun, is the head of the Etherow, one of the tributary streams of the River Mersey, which runs westwardly to Liverpool.

"As the natural course of these rivers appeared to point out the line of direction, I had accurate surveys and sections made by an experienced engineer, of all the valleys connected with them, in order that a correct judgment might be formed of their various capabilities.

"In pursuing the right bank of the Dun, from the town of Sheffield westwards,* three different vales present themselves; the lower parts of which afford facilities for the construction of a canal; the first leading to Bradfield, the second to Yewden Brook, the third by Midhope, besides that formed by the Dun itself from its source.

"At the summit of each vale, the high ridge of country before alluded to, presents, at different degrees of elevation, a barrier which can only be passed by means of a tunnel, the particulars of which are accurately delineated in the plans and sections.

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* Or rather, *Northwards.*

"On inspection of these documents it will appear that the lowest summit is at the head of the Dun, at Windleden Cross, which measures 1203 feet above the level of the water in the Dun at Kelham Wheel weir, near to the town of Sheffield. If a tunnel be made to this summit, to cut off 403 feet at the top, the length will measure two miles and 37 chains.

"The summit next in succession is that of the Midhope; its elevation is 177 feet above Windleden Cross, or 1380 feet above the water in the Dun, and the length of its tunnel at the altitude above mentioned, viz. 800 feet above the level of Kelham Wheel weir, measures four miles and a half; but the length of the canal would be shorter by this line than by the course of the Dun, four miles and a half, nearly; a circumstance, however, which renders it more inconvenient for the placing of the requisite number of locks at proper distances.

"The summit on the Yewden Brook line is 1440 feet above the water in the Dun; and the length of its tunnel, at the same elevation as the others, measures six miles five furlongs; this, however, is the shortest navigation line of the three, being 5½ miles less than the one by the Dun; *but the steepness* *of the inclined plane in this vale, renders it unfit for receiving locks**.

"The summit of the Bradfield line passes under Pike Saw, at an increased elevation of 150 feet, and its length is nearly eight miles†.

"Supposing, therefore, each of these vales to afford equal facilities for the construction of a canal, the relative heights of their different summits, and the respective lengths of their tunnels, decide the question as to their comparative merits, with regard to the facility and expense of execution.

"The line of the Dun, being therefore, from physical causes, if not the only practicable one, at least greatly preferable to the others; the plans and estimates have been completed with a view to its execution.

"This line commencing near Neepsend, generally proceeds along the right bank of the Dun, except where it is necessary to cross for any particular advantage for a short distance, to the proposed summit under Windleden Cross; having a succession of 80 locks between Sheffield and the tunnel*. The whole of this line is exceedingly favorable for the execution of a canal; the soil throughout is of the most friendly nature; and the adjacent hills contain stone of the best quality for buildings of this description.

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* This being the case, why take the trouble to level over the summit, and state the length of the tunnel? One would have thought Mr. Telford's *experienced* engineer would have employed his time better.

† More useless, though not *unprofitable* labour; but here is a trifling mistake; it is not *this*, but the Yewden Brook line, which passes under Pike Saw.

"After passing this tunnel, the canal proceeds on the north side of the Etherow vale to Tintwistle; where it skirts round the hill side, passing under Mottram, so as to reach the level of the Court House at the head of the Brook which runs down to Hyde. This line also, with the exception of a rugged hill side for a short distance below the tunnel, and a piece of rocky ground near Woodhead Chapel may be considered as easy of execution, and the soil of good quality. The whole length measures 39 miles and 17 chains.

"The supply of water is provided by six spacious reservoirs, three above the valley of the Dun, and three above Saltersbrook on the Etherow; the quantity, therefore, of water, will be fully adequate to any trade which may exist*.

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* The line crosses the Dun seven times between Sheffield and Penistone; and besides the 80 locks on the eastern side of the tunnel, it will have no less than 66 on the western side, each lock being 10 feet deep.

"Although the soil throughout the whole of the line appears of the most favorable nature, and although materials of the best quality are so contiguous, yet it must be admitted that the summit is unavoidably much elevated.

"In the estimates which I have made, I have calculated the costs of a canal for 60 ton barges, as well as one for boats of 20 tons; and I have made a comparative estimate likewise of lowering the tunnel 603 feet from Windleden Cross, so as to reduce the lockage 200 feet on each side of the summit.

"The amount of the expense of a wide and narrow canal, approximates much nearer than is usual; but that is attributable to the great proportion of lockage which, excepting the inverted arches at the bottom of the locks, and lock-gates, are, with respect to the masonry, nearly alike in both.

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* Notwithstanding Mr. Telford's "*therefore*," I do not think his demonstration of this problem is quite clear; as it depends entirely upon the extensive signification of the word 'spacious,' which may imply an area of ten, or twenty, or one hundred acres. Upon reference to a copy of Mr. Telford's plan, I find that each of these intended reservoirs covers, upon paper, a space equal to twenty acres; but they are perhaps not laid out with precision. It is, however, of the utmost importance, when the summit-level is placed so high, to be assured of sufficient water for the navigation; and the public ought to be quite satisfied on this point before they subscribe to the project. It should be remembered that the summit-level of this line is between four and five hundred feet higher than that of any canal in the kingdom.

"The estimate of the wide canal for 60 ton barges amounts to £499,231, and that of the narrow canal to £414,278.

"The expense of a wide canal, supposing the tunnel to be constructed so as to take off 200 feet of lockage at each end, would be increased to the amount of £763,521; and although the time to construct this tunnel would be lengthened, unless recourse was had to excavation by the means of shafts, in which case it might be executed within the period of completing the other works, yet it would bring the navigation into more reasonable limits as to elevation, and would increase the supply of water as well as create a great saving of time; an object in the present improved state of commerce, and particularly if considered as a rival mode of conveyance, of the greatest moment.

"It may be expected probably, that I should say something of the probable return likely to be made to the subscribers for such an expenditure; but the gentlemen of the country, who are more intimately acquainted with its resources than I am, will be more competent judges upon this subject*. I may, however, state that independent of the conveyance of general merchandize, and of the exchange of manufactures between Sheffield and Manchester, a canal which has an abundant supply of coal at the east end in the parishes of Ecclesfield, Tankersley, and Silkstone, and which terminates against the mountain limestone of Derbyshire by its junction with the Peak Forest, and with the great demand for coal which the cotton manufactures on its western extremity must create, cannot but produce a great annual revenue†; but this part of the subject not falling under the principle of civil-engineering, will, with more propriety, be investigated by those connected with the manufacturing and commercial interests of the country, and possessed of local knowledge, which I have had no opportunity of acquiring.

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* Mr. Telford has very wisely declined giving a definite opinion concerning the annual revenue; since he cannot but entertain some doubts of its being adequate to the expense. He contents himself, therefore, with saying that the revenue will be *great*; how great it is likely to be, the committee and the public are left to determine for themselves.

† It happens unfortunately for the proprietors of coal-beds in the parishes mentioned by Mr. Telford, that they are not likely to vend their coals at the western extremity of this line, even if a canal were actually in operation; because there are coal-works in the immediate neighbourhood, sufficiently extensive to meet the great demand at half the price of such as would have to be conveyed a distance of nearly 40 miles, along a line of navigation rendered tedious by numerous locks. And with regard to the representation that this line terminates against the mountain limestone of Derbyshire, it is really quite incorrect. The line would undoubtedly *communicate* with the limestone rocks through the medium of the Peak Forest Canal and its railway; but not without rising 800 feet to Windleden, then descending 660 feet to Hyde Lane, then rising again 215 feet to the basin at Bugsworth, and 625 feet more, by railway to the quarries; being altogether a distance of 59 miles from Sheffield with a total rise and fall of 2300 feet perpendicular; and would require five days to convey to Bugsworth a boat load of coals, and the same length of time to return with a load of lime.

(Signed) "THOMAS TELFORD."
London, Jan. 7th, 1825.

Previously to Mr. Telford's report being obtained, the projectors of this line gave notice of their intention to apply to parliament for an act in the then-ensuing session. No such application, however, took place; and the project slumbered in the office of the clerk of the peace for the space of a whole year; when, in the month of November last, a public meeting was convened which no doubt led many to suppose that an application was to have been made during the *present* session; but it is again deferred till the *next;* and, in the mean time, those gentlemen, merchants, manufacturers, and others who are interested in the welfare of Sheffield, and consequently anxious to facilitate the conveyance of her manufactures westwardly, as well as the interchange of mineral productions in that direction, have a favorable opportunity for obtaining such information as will enable them closely to compare the several proposed lines with each other; and after so doing, to decide judiciously for or against the projected undertaking entitled the Sheffield and Manchester Junction Canal.

Comparison of the proposed Sheffield and Manchester Junction Line with other practicable Lines of Canal.

The Grand Commercial project having apparently fallen to the ground, it remains only for me to place by the side of the proposed Sheffield and Manchester Junction Canal, which for the sake of brevity I will call '*the Penistone Line,*' such other lines as have been surveyed, though the consideration of them has not formed the ground of a public meeting.

Mr. Thomas Bishop proposes to ascend the vale of the Sheaf, and tunnel a mile and three quarters under the Moors to Smeecliff Wood; thence, to pass by another tunnel of three miles and a quarter to Froggatt Edge, opposite Calver; whence his line proceeds, in open day, along the vale of Derwent, Hope-dale, and Castleton-dale, to the Odin Mine. After having drained this mine*, it is to pass under the well-known shivering mountain called Mam Torr, and through various unknown strata, a distance of five miles further by tunnel, till it reaches the Wash near Chapel-Milton; a little beyond which village, its junction with the intended extension of the Peak Forest Canal would be effected. This I will designate '*the Castleton line.*'

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* If Mr. Bishop's level will accomplish this object, the proprietors of the mine ought to subscribe handsomely towards his project.

There are three other lines which I have myself surveyed, and by which a junction may be effected with the line laid down by the late Mr. Rennie in 1810; having the same summit-level and, consequently, the same supply of water as was designed by that very able engineer.

One of these lines, which may be termed '*Edale line, No.* 1,' passes up the Porter Valley as far as Smith Wood; where it turns towards the north-west, under Rand Moor and Sandy-gate hill. A tunnel seven furlongs in length brings it into the Rivelin Valley, up which it may be carried as far as the junction of the Wyming Stream with the Rivelin, when tunnelling again becomes necessary. After passing a distance of four miles further under-ground, the line emerges from below Bamford Edge; and running near the Glossop Road a short distance, crosses the Derwent by an aqueduct, and proceeds along Ashop-dale to Grimber Carr. Here a short tunnel of half a mile through Win-hill-ridge into Edale, brings this line in contact with that of the once-intended High Peak Junction Canal, which may be thence-forward very safely adopted; having received the united approbation of the late

Mr. Rennie, and Messrs. Brown and Meadows, of Manchester; by whom, or by some assistant of Mr. Rennie, it was surveyed and planned with all the attention and accuracy requisite for a formal application to parliament.

Another line may be carried up the valley of the Porter as far as the junction of the two streamlets which form that brook; and a tunnel five miles in length under the moors would carry it out a little beyond Hathersage; whence it may be continued, on the same level, to Mr. Rennie's line, and a junction effected therewith at the east side of his proposed aqueduct over the Derwent, near the Bamford Cotton Mill. This I shall entitle '*Edale line, No. 2.*'

The third, or '*Edale line, No.* 3,' goes up the vale of the Sheaf, as proposed by Mr. Chapman in 1813; but instead of joining Mr. Rennie's line near Padley Mill, I propose to make the level of the tunnel 90 feet lower than was then intended, and continue the same level along the side of the hills till it runs into that line near its intersection with the Castleton Turnpike Road*.

The Castleton, and the three last-mentioned lines all unite with the Sheffield Canal-basin; and though the breaking of bulk is unavoidable, on account of the vessels which navigate the Dun being too wide for the Peak Forest Canal, while the boats used on that canal are too narrow for an open river, it is no doubt much easier to transfer a load immediately from one boat to another lying alongside each other, than to carry the goods a mile in carts upon a common road for that purpose. This circumstance alone renders any line commencing at the Sheffield Canal-basin greatly preferable to that which cannot approach within a mile of it; and in such a predicament stands the Penistone line, which stops short at Neepsend.

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* By making this tunnel lower, it would be half a mile longer than was stated in Mr. Chapman's report.

It appears to be a matter of doubt whether it be better, in crossing a mountainous country, to carry the summit-level of a canal very high, and so avoid tunnelling by losing time in lockage and hazarding the supply of water; or by keeping a very low level, to save time and make sure of water, although at the risk of a ruinous expense in tunnels. Indeed, I have heard it suggested that in forming a plan for joining the Sheffield with the Peak Forest Canal, we ought to ascend no higher than the difference of their respective levels; and Mr. Thomas Bishop appears to have almost adopted this idea, while Mr. Telford's plan is not far from the opposite extreme. If we take the mean of the respective elevations of their summit-levels above the Sheffield Canal-basin, we shall find it to correspond very nearly with the elevation of that recommended by Mr. Rennie*.

The great length of time spent in passing locks operates very strongly in favour of tunnels; especially when expeditious conveyance is required, and where the traffic will be sufficient to pay usual interest on the additional cost of tunnelling. To avoid delay at the mouth of a tunnel, it should be made wide enough for two boats to pass each other; and in order to proceed through it at the same rate as in the open canal, there should be a towing-path for horses†.

The locks upon the Penistone line are intended to be 10 feet deep and 80 feet long so as to contain four boats at once; we must, therefore, allow at least 10 minutes for the passing of each lock. It may be possible to do it in less time; but we ought to consider what would be the general length of time so occupied, when there is no extraordinary inducement for the boatmen to hurry themselves.

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* Mr. Telford's line rises 800 feet, Mr. Bishop's 480 feet, and Mr. Rennie's 630 feet, above the level of the Sheffield Canal-basin.

† The clear width of the tunnel ought, for these purposes, to be at least 22 feet; which would admit two such boats as are used on the Peak Forest Canal, and a towing-path six feet wide. If the arch be semicircular, there would be about 35 solid yards to be excavated in every yard lineal, including the space occupied by the arch and walls.

Assuming 10 minutes to be the average time of passing each lock, and that a boat laden with 20 tons would be hauled by a horse at the rate of 2½ miles an hour, I have calculated the length of time required to convey that weight along each of the proposed lines, from the Sheffield Canal-basin to the Peak Forest Canal at Hyde-lane, to be as follows:—

	h.	*m.*	*h.*	*m.*
Penistone line.				
Land Carriage	2	30	42	32
Canal 39¼ miles	15	42		
Locks 146	24	20		
Castleton line*.				
Canal 43 miles	17	12	30	52
Locks 82	13	40		
Edale line, No. 1.				
Canal 36 miles	14	25	33	5
Locks 112†	18	40		

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* My calculations respecting the Castleton line are founded upon the public statements of Mr. Thomas Bishop, as to its levels and the course which it takes. The length of the line which I have here given, and that of the tunnels previously stated, are not from actual admeasurement upon the ground, but are derived from the best Maps which I could procure. I feel confident, however, that they are not *overrated*, but rather the contrary.

† I take the fall of the Peak Forest line from Chapel-Milton to Hyde-Lane, as though it were divided into locks of 10 feet each.

	h.	m.	h.	m.
Edale line, No. 2.				
Canal 37½ miles	15	0	33	40
Locks 112	18	40		
Edale line, No. 3.				
Canal 40 miles	16	0	34	40
Locks 112	18	40		

Reckoning 10 hours to be a day's work on the Penistone line, it would require four days, to convey a boat load of goods from Sheffield to Hyde-Lane. Upon the Castleton line it would only require three days, and upon the Edale lines about three and one-third; but they would manage to go in three days on the latter as well as on the Castleton line, by making a day's work 11 hours instead of 10.

Though the Castleton line requires so much less time on account of its having so few locks compared with the Penistone line, it has, on the other hand, an excessive length of tunnelling; and it is important to enquire, to what amount expense may profitably be incurred, with a view to the saving of time.

Mr. Telford himself seems inclined to recommend a long tunnel, for the sake of a lower summit-level; but the Committee of the Penistone line have decided in favour of the higher tunnel and less expense; thinking *cheapness* more to be desired than *celerity* of conveyance, where the traffic is expected to consist principally of minerals and other heavy goods.

The Edale line, No. 3, saves 8 hours time at the expense of 3½ miles of extra tunnelling; while the Castleton line only saves 11¾ hours at the expense of 7½ miles of extra tunnelling, part of which will, in all probability, pass through limestone. Therefore, with regard to time and expense together, the Edale line, No. 3, is preferable to the Castleton line; for although it may be worth while to shorten the voyage 8 hours by making 3½ miles of tunnel, it is not worth while to strike off only 3¾ hours more, by tunnelling four miles further.

I will now proceed to the consideration of that most important part of the subject, the amount of capital required to carry the project into execution, and the annual revenue which is likely to accrue from it when completed. It is not necessary to enter into minute details in order to obtain satisfactory comparative information on this head; my estimates will, therefore, be general.

Judging from the expense of similar

works, I should suppose that canal-locks 80 feet by 16, and 10 feet deep, where ashlar-stone is plentiful, could be constructed at the price of £1000 each; and a tunnel through gritstone, 2½ miles long and 22 feet wide, would not cost more than £15 per yard lineal, if managed judiciously. A long tunnel will cost more per lineal yard than a short one, on account of the greater distance which the excavated earth has to be removed*. The open parts of a narrow canal, including bridges, aqueducts, culverts, towing-paths, purchase of land, new fences, &c. should be estimated at no less than £5000 per mile; and the expense of reservoirs may be taken at £15,000 for the Penistone line, £10,000

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* The difference in expense per lineal yard will be £1 for every half-mile in length, the area of the opening being 35 square yards; and taking the tunnel of one mile at £12, I have by this rule formed the following scale of prices per yard, for tunnels of different lengths, through shale and gritstone in equal proportions.

	£	s.
Half a mile	11	0
¾ of a mile	11	10
1 mile	12	0
1½ miles	13	0
2 miles	14	0
2½ miles	15	0
3 miles	16	0
4 miles	18	0
5 miles	20	0
10 miles	30	0

This calculation will shew the reason of the enormous difference between Mr. Telford's estimates for a high and a low summit-level; the latter exceeding the former by £264,290, notwithstanding the saving of £40,000 in locks. The lower level would require a tunnel of eight miles in length; and supposing the width to be calculated for a narrow canal, the price per yard would be £26, while that of the higher and shorter tunnel would only be £15.

for the Edale lines, and £5000 for the Castleton line. As the Mam-Torr tunnel in the latter would probably pass the distance of a mile through the limestone strata which lie under the shale, I estimate that length at double the expense, per yard, of the other part of the same tunnel.

Taking these *data* for the foundation of a general comparative estimate, the respective cost of each line will stand as follows:—

	£
The Penistone line (exclusive of Warehouses)	410,750
Castleton line	488,700
Edale line, No. 1	394,570
Do. No. 2	417,570
Do. No. 3	357,400

Having ascertained the gross amount of the first cost, it should next be considered whether the probable annual income will pay the usual interest of five per cent. on the capital employed, after deducting the expences of repairs. This is by far the most difficult part of the subject; and, indeed, it is impossible to form anything like a correct estimate, without a great deal of trouble.

Mr. Telford says, in his report on the Penistone line, that this part of the subject does not "fall under the principle of civil engineering;" but at the same time informs his employers that his opinion is in favour of a great annual revenue. Whether it be great or small, there can be no doubt that the most expensive of the Edale lines would produce a far greater *clear* interest upon its capital, than the subscribers to the Penistone line would ever receive; because the expense of repairs would be less by one half, and although the tonnage with regard to the number of miles would be less, the traffic in lime and coals would be much more extensive on the former than it would be on the latter line. The great distance which lime would have to be conveyed to Sheffield by the Penistone line, would prevent its consumption on the surrounding lands, in anything like the same quantity that would result from the opening of a much nearer channel; and so long as there is plenty of coal to be had from the pits in the neighbourhood of Bugsworth and Whaley, none will go thither by a navigation of more than 50 miles, over a rise and fall of 1700 feet. Such a speculation as this would be much the same thing as sending coal to Newcastle.

On the other lines, the case is quite different; as a considerable portion of their income would arise from the traffic in coal and lime; and the low price at which the latter could be conveyed to Sheffield from Bradwell or Calver, would cause an incalculable increase in the demand for it. If there were to be any difference in the amount of tonnage arising from general merchandize, it would also be in favour of that line which unites with the Sheffield Canal; as such an union would render the transit of goods from Manchester to the River Dun Navigation more easy than it could be effected through the Penistone line; from the intended basin of which to the Sheffield Canal-basin, there would be a mile of land carriage. With regard to the other articles of traffic which would become permanent sources of revenue on the Penistone line, I know of none that would not find its way along the Castleton or Edale lines. Agricultural produce, ashlar-stone, slates and paviours, are likely to be as plentiful commodities on one line of navigation as the other.

All the Edale lines are, therefore, decidedly preferable to the Penistone line, not only on account of the very considerable saving of time to boats passing through the country with general merchandize, but because of the great facility which they would afford for the exchange of mineral productions at a cheap rate. Two of them are also superior in point of economy; for, with the prospect of a greater profit, they require a smaller capital; No. 3 would not cost so much as the Penistone line by £53,350. In this respect these lines must also be deemed greatly preferable to the Castleton line, unless some very substantial reason can be given for incurring the enormous expense of the latter; which exceeds that of the Penistone line by £78,000, and that of the Edale line, No. 3, by £131,000.

Although the Castleton line, by going to Smeecliff Wood, would throw open an additional supply of coal for the limestone district, which would probably have the effect of reducing the price of both articles, the extra demand occasioned thereby would not produce an increase of revenue proportionate to the extra expense. A more lasting supply of coal for the future use of the Sheffield manufacturers, is also undoubtedly very desirable; but there is no occasion to pay too dear for an object so remote. In the course of a few years, a junction of the Sheffield and Chesterfield Canals will, in all probability be effected, in the line suggested more than thirty years ago by the late Mr. Benjamin Outram, which passes under Tinsley Park wood, and along the vale of the Rother through Orgreave and Beighton to Killamarsh; a part of the country where coal abounds, and where the Derbyshire lime would be had in great demand.

It is generally considered that if the

annual income of a canal amounts to 10 per cent. upon the capital invested, it will yield 5 per cent. to the share-holders after all the annual expences are defrayed. But when a considerable portion of the first expense has been occasioned by tunnels, the annual expense of repairs, &c. will not bear so great a proportion to the first cost as in cases where there are no tunnels; or, if any, only of a short length. We ought to calculate 5 per cent. upon the cost exclusive of the tunnels; which upon the Penistone line amounts to £17,235; upon the Castleton line to £7,275; upon the Edale line No. 3, to £9,525; upon No. 2, £8,450, and upon No. 1, £7,950 per annum. These sums added respectively to the interest of 5 per cent. upon the whole capital required for each line, makes the total annual income which ought to arise from any one of the several projects, if carried into effect, as follows:—

		£
Penistone line		37,772
Castleton line		31,710
Edale line,	No. 1	27,675
Do.	No. 2	28,960
Do.	No. 3	27,395

from which it will be seen that the Penistone line should have a yearly income £10,000 larger than would be necessary on two of the Edale lines, in order to pay the common interest of 5 per cent. But it appears to me extremely improbable that any such revenue as the above, would ever be collected yearly on the Penistone line; and very doubtful that the annual income from any line of canal to be made between Sheffield and the Peak Forest Canal, would exceed £20,000, even with the advantage of a near approximation to the mountain limestone of Derbyshire. If any line will yield as much, it must be that which presents the greatest facilities for a cheap conveyance of mineral productions, with an expeditious passage for general merchandize. No more than twopence per ton, per mile, ought to be charged as dues for the latter, nor more than onepenny per ton, per mile, for the former; at which charge, supposing the freightage to be the same, and a branch railway made from the Castleton or any of the Edale lines to the Limestone rocks, the price of lime at Sheffield and of coal at Calver or Bradwell would each be about eight shillings per ton. But lime brought to Sheffield by the Penistone line, paying the same dues and carriage per mile, could not be afforded for less than *sixteen* shillings per ton; being double the price for which it could be obtained by the Castleton or Edale lines, and not much cheaper than it is at present delivered after having been carted across the moors. This fact is very much against the opinion of Mr. Telford in favour of a large revenue on the Penistone line.

It is my opinion, and I have already stated it, that an income of twenty thousand pounds per annum is by no means *certain* upon any of these lines; and if this opinion be correct, I may be permitted to ask,—would it be prudent to expend so large a sum as £420,000 in the construction of a narrow canal through a mountainous district, when an edge-railway of the most superior description may be formed for little more than one-third of the money, and would answer every *general* purpose which can possibly be desired?

In the following part of this publication I shall endeavour to shew that a well-constructed edge-railway is, in many respects, superior to such a canal; and will then leave the preceding question for the consideration of the candid reader.

For the purpose of facilitating a comparison of the several proposed lines of canal with each other, I have constructed the following Table which exhibits at one view every particular of importance. My statement of the summit-level on the Penistone line is made under the supposition that Kelham-wheel-weir is on a level with the Sheffield Canal-basin; if there be any error in this supposition, it is so trifling as to be of no importance in the present comparison.

TABLE

OF THE PROPOSED LINES OF CANAL.

	Penistone Line.	*Castleton Line.*	*Edale Line, No. 1.*	*Edale Line, No, 2.*	*Edale Line, No. 3.*
Length of new Line, in miles	39¼	28½	22	23½	26
Length of Tunnels, in do.	2½	10	8¼	7¾	6
Distance to Manchester from the Sheffield Canal-basin, in miles	48½	51½	44¼	46	48½
Distance to the Derbyshire limestone rocks from Do, in miles	59	12	15½	13½	13
Greatest deviation from a straight line between the two towns, in miles	8¼	8½	7¼	7¾	7¾
Height of summit-level above the Sheffield Canal-basin, in feet	800	480	630	630	630
No. of 10 feet locks in the new Line	146	48	78	78	78
Total Rise and Fall between Sheffield and Chapel-Milton, in feet	1800	480	780	780	780
Total Rise and Fall between Sheffield and Hyde-Lane, in feet	1460	820	1120	1120	1120
Total Rise and Fall between Sheffield and Piccadilly, Manchester, in feet	1620	980	1280	1280	1280
Probable amount of the First Cost	£410,750	£488,700	£394,570	£417,570	£357,400
Smallest annual Revenue, to clear 5 per cent. after deducting repairs	£37,772	£31,710	£27,675	£28,960	£27,395

Having given a description of the several lines which have been suggested for a navigable canal, it is proper that I should also describe that which I have laid down for an edge-railway, previous to entering upon a consideration of the advantages which are presented by this peculiar mode of conveyance.

The line which I have suggested, and I am not aware of any other for effecting a junction with the Peak Forest Canal, commences at the Sheffield Canal-basin and passes along the east bank of the Sheaf. After skirting the south-east quarter of the town, it goes a short distance up the Porter valley; then climbs upon the high ground above Nether Green, which may be accomplished by two steam-engine inclined planes, and proceeds along the ridge to Soughley Ings; thence, crossing the Wyming Brook, it ascends that side which inclines towards the Rivelin, with an easy rise, till it arrives at the division of the counties near its intersection with the Sheffield and Glossop Turnpike Road*. This point is the higher of the two summits which must necessarily be crossed by the proposed railway.

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* Since this pamphlet was sent to the press, it has been suggested to me that a line may be carried to the same point by the valleys of the Dun and Rivelin. Not having surveyed this line, I cannot give an opinion or state any facts concerning it; but think it probable that it would, if practible, prove very expensive; owing to the quantity of buildings which stand in the way, and the bridges which would be required to cross the River Dun twice, as well as one over the River Loxley.

After entering Derbyshire the line begins to descend; and two more steam-engine planes must be made use of, to carry it down to the level of a high bridge which would be required over the River Derwent near Ding Bank.

Having crossed the Derwent below its junction with the Ashop, the line proceeds along the south side of the latter river to Grimber Carr; where a tunnel of half a mile in length may be readily opened into Edale, near the farm house called Fearny Lea. It then ascends the vale of Edale to the foot of Cowburn Ridge, above Barber Booth; and must be carried through this ridge by another tunnel of one mile and three-quarters in length, which will form the second summit.

Between the west end of the proposed tunnel under Cowburn Ridge and the Peak Forest Railway at Chapel-Milton, a fifth steam-engine plane will be required to reduce the inclination within proper bounds.

Thus there must necessarily be in this line, five steam-engine planes, having a total rise and fall of 1050 feet perpendicular, and two tunnels, together 2¼ miles in length; in order to avoid, in those parts of the line whereon locomotive power would be used, a greater inclination than 1 in 84. This inclination is the same as that of the Peak Forest Railway between Chapel-Milton and Bugsworth; and I shall endeavour presently to shew that it is not too steep for the advantageous use of either horses or locomotive engines.

The lengths of the several degrees of inclination in the proposed line, are as follows:

m.	*f.*	
1	6½	1 in 9
11	5	1 in 84
1	6½	1 in 100
2	5	1 in 115
1	4½	1 in 412
2	4	level.
21	7½	

Mr. Jessop has laid out the Peak Forest and Cromford Railway in such a manner, that those parts which lie between the steam-engine planes will be level, excepting a length of 3½ miles, the inclination of which will not exceed 1 in 396, or one-eleventh of an inch in a yard. But however desirable such a plan may be esteemed, it could not be adopted in the line under consideration, without incurring too great an expense in the numerous fixed steam-engines which would be required. The Peak Forest and Cromford line rises to the height of 1000 feet above the level of the canal at Whaley, and after continuing some distance on that elevation, descends without interruption to the Cromford Canal, having only to pass over one summit. In this line the case is different; as there are two summits to be crossed, occasioned by the intersection of the Derwent valley. It has consequently a double rise and fall amounting to 2065 feet in 22 miles; while the total ascent and descent of the Cromford line is only 1747 feet in 30 miles. There would also be, in the line under consideration, many difficulties to overcome in the formation of a level plane, particularly at the Sheffield end, which do not present themselves in the Peak Forest and Cromford line of railway.

That the first cost and subsequent expenses attendant upon the use of fixed steam-engine planes is very considerable, I need not attempt to prove; it will be prudent, therefore, to avoid the use of this expensive kind of power as much as possible, by giving the railway such a degree of general inclination, as will not prevent a horse from drawing up four tons weight of goods, exclusive of the carriage, in one load*; which is enough for the quantity of traffic that may reasonably be expected upon this line, and is equal to three two-horse loads upon any of the turnpike roads which cross the grand ridge.

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* The weight of a railroad carriage is generally one third of the weight of its load; therefore, a load of 4 tons will be 5 and one third tons, including the carriage.

If a horse can ascend the proposed line of railway with a load of four tons, a locomotive engine weighing eight tons, including a ton of water, will be able to drag up in the most unfavorable weather a weight of twelve tons, exclusive of the carriages; and in the most favorable weather, as much as thirty-six tons weight. The power of such an engine depends entirely upon the degree of force with which its wheels adhere to the rails; and this force is materially affected by the state of the weather, which is most favorable when very dry, and most unfavorable when rather moist; the rails being then partly covered with mud, which, acting like oil upon an axle, reduces the quantity of attrition, and causes the wheels to slide instead of turning round, if it be attempted to drag the same weight as is practicable in dry weather. The power of adhesion in very wet weather is almost as great as when it is very dry.

Taking the performance of a locomotive engine upon an inclination of 1 in 84, at a mean of 12 and 36 tons, it is more than equal to the burden of such boats as are used on the Peak Forest Canal; and as the velocity of the engine, including stoppages at the fixed-engine planes, would be double that of a canal boat where there are *no locks*, the superiority of a railway conveyance in a westward direction from Sheffield is so very apparent, that one would imagine it must be acknowledged by every candid and reasonable person.

It has been said that horses and locomotive engines cannot be used on a railway at one and the same time; but I am not aware of the reason why they cannot. A horse could easily turn out of the main line to let an engine pass; and as the latter would not travel generally at a greater rate than six miles an hour, it might also be turned out with almost equal facility, at any of the places which would be constructed for that purpose.

By using both kinds of power, a greater accommodation would be presented to the public. Persons who wished to have a small weight of goods conveyed without delay, would avail themselves of horse-power, though at a greater expense; but if a moderate delay were no object, they would wait till a sufficient load was obtained for a locomotive engine. A light weight of valuable goods, or even passengers, might be conveyed by a horse at a rate of motion equal to that of an engine; for, by reducing the load, his speed may be proportionably increased, to a certain extent. With a load of two tons, a horse would travel along the proposed railway at the rate of five miles an hour; and with only one ton, at the rate of ten miles an hour, provided the carriage bear the same proportion to the weight as in a heavier load. The velocity of a locomotive engine may also be increased beyond six miles an hour, when the resistance of the load is less than the effective power of the steam.

I will now proceed to explain the rules whereby I calculate the weight which can be drawn up the proposed line, by either kind of power.

The weight which a horse can draw upon a level railway at a given speed, depends upon the proportion which the friction of the carriage bears to the weight of the load, and which is influenced by the ratio of the diameter of the wheels, to the diameter of the axles.

The resistance from friction, with wheels and axles of a certain size, being first ascertained, its amount with wheels of any other size upon the same axles can be readily calculated therefrom; since it is known to vary so nearly in an inverse ratio to the proportion which the diameter of the wheels bears to that of their axles, that it may safely be considered so for every practical purpose. All the difference which can arise will be occasioned by the unevenness of the surface of the rails, and any earthy particles which may have accumulated upon them; if they were perfectly smooth and clean, there would be no friction but that of the axle; and in that case it must vary in exact proportion to the diameters of different wheels used upon the same axles*.

It has been proved by experiments upon the edge-railways near Newcastle-upon-Tyne, that with a loaded carriage upon three-feet wheels and three-inch axles, the friction is equal to the 216th part of its weight, therefore with four-feet wheels on three-inch axles the friction will be, by the preceding theorem, no more than the 288th part of the weight†. The proportion of the axles to the wheels in the first case being as 1 to 12, if we divide 216 by 12 it gives 18 for a multiplier, to find the friction with wheels and axles of any other proportion. Then, supposing axles of the same diameter to be used with wheels of 3½ feet diameter, the proportion will be as 1:14; and 14 multiplied by 18 gives 252 for the proportion which the weight bears to the friction, the latter being represented by unity; and with four-feet wheels, the proportion being as 1:16, this multiplied by 18 gives 288 as before stated.

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* There is another cause of obstruction to the motion of carriages upon a railway, and that is, the opposition of the wind; but at a moderate velocity this obstruction is so trifling as to be unworthy of notice.

† Mr. Jessop says, in his second Report on the Peak Forest and Cromford Railroad, that the friction of a loaded carriage is the 200th part of its weight; but it is probable he calculated upon three-feet wheels. On tram roads the amount of friction is never less than 1-90th part of the weight, which is a sufficient proof of their great inferiority to edge-railways.

But we need not calculate for wheels of less diameter than 4 feet, since they may be used upon a railway of a proper breadth without either danger or inconvenience; and as 3½ inch axles will be quite strong enough to sustain the weight which I propose each carriage should contain, I may without hesitation assume the friction at 1-150th part of the whole weight of the carriage and its load together. Larger than 4 feet wheels would be unsafe as well as inconvenient, and smaller ones would cause a useless expense of power.

The use of small wheels is one reason why the performance of horses is so inferior upon all the tram-roads or plate-railways. Other causes are the imperfect manner in which such rails are generally laid down, and their liability to be covered by the dirt or gravel from the horse-path, producing together a very serious obstruction to the rolling of small wheels; which, added to the unnecessary size of the axles, the narrow width of the bearings, and the neglect of case-hardening the rims of the wheels, makes the amount of friction upon such railways three times as great as it need be upon a well-laid edge-railway, with carriages constructed upon scientific principles.

If a railway has any inclination, the gravity of the load will be a retarding force when ascending the plane, and an accelerating force when descending it. The amount of this force is to the weight of the load, as the height of the plane is to its length*.

For instance: on those parts of the proposed railway which have an inclination of 1 in 84, the gravity of a load weighing 5⅓ tons, including the carriage, is 142lbs; and the friction being 48lbs. the excess of gravity above the friction in descending will be 94lbs.

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* Mr. Telford is stated to have said that upon an inclination of 1 in 98, a horse will take down from 12 to 15 tons exclusive of the carriages (about 18 tons altogether,) and return with 4 tons in the same carriages (about 8½ tons.) See '*Illustrations of the Origin and Progress of Rail and Tram Roads,*' by T. G. Cumming, Surveyor—page 58.

If this representation be correct, it proves that Mr. Telford has not, in this instance, correctly calculated the force of gravity, or that he has estimated the power of the horse much higher even than Dr. Desagulier who states it at 200 lbs. moving 2½ miles an hour.

Supposing the friction to be no more than the 270th part of the weight, (which will make the resistance in going up the plane equal to the difference of the gravity and resistance in going down,) the power of the horse must have been considered by Mr. Telford equal to 260lbs.

and the total resistance in ascending will amount to 190lbs. But the power of a good horse is generally estimated at 150lbs. moving at the rate of 2½ miles an hour; therefore, in descending with this load, the horse would have to hold back with a force of only 94lbs. if there were no brake applied to the wheels; but in ascending he must exert a more than common effort, the extra resistance being equal to 40lbs. This, however, would do the horse no harm; because he would not have to exert a greater force than 48lbs. on the level parts of the line; and on the descending parts he would only have, by holding back, to assist the brake in preventing too rapid a descent of the load. The horse would also have a respite from labour while the load was passing the steam-engine planes.

The mean resistance of a loaded carriage weighing 5⅓ tons, throughout the proposed line exclusive of the steam-engine planes, will be 142lbs.; and the number of miles in which locomotive power would be required is rather more than twenty; so that, upon the whole, it may be considered a fair day's work for a horse to take a load like this the whole distance in 8¾ hours, which is at the rate of 2½ miles an hour; ¾ of an hour's time being occupied in passing the steam-engine planes.

In returning to Sheffield, the journey would be much easier; the mean resistance of the load being only 98 lbs.; therefore, one day with another, the average work of a horse upon this line would be 20 per cent. below its estimated power.

The weight which a locomotive engine can drag upon a railway is limited, as I have before observed, by the degree of force with which its wheels adhere to the rails. This force has been found by experiment on the railway at Killingworth Colliery to be in the most favorable weather, nearly equal to one ninth of the engine's weight, (including water;) and in the most unfavorable weather, the adhesive power is to the weight as one is to twenty-one, nearly.—Supposing the engine, with a ton of water, to weigh 8 tons, the former will be 1930 lbs. and the latter 840 lbs., the mean of which is 1385 lbs.; being more than equal to the estimated power of nine horses*.

Upon an ascent of 1 in 84, two ninths of this power are expended in overcoming the gravity of the engine, and the convoy carriage which contains the supply of fuel and water; and the remaining seven ninths will drag six times the weight which I have allotted for a single horse, at more than double the velocity. The reason why only *six* horse-loads are considered sufficient for the estimated power of *seven* horses in the engine, is because a horse can exert an extraordinary degree of force upon the greater ascending inclinations, which will be counterbalanced by the relaxation which he will experience on the more level and the descending parts of the line; but the effective power of an engine depending upon the amount of its adhesive force, it cannot be so varied.

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* Mr. Jessop is of opinion that *one tenth* of the engine's weight should be calculated upon as the adhesive power. This proportion would amount to 1792 lbs. being 407 lbs. more than the mean result of Mr. Wood's experiments. Mr. Tredgold, author of a treatise on rail-roads, thinks *one twelfth* a sufficient estimate, and makes his calculations on that datum, although it is not the result of actual experiment.

In descending the inclinations of 1 in 84 with a locomotive engine, it would be necessary to use brakes or convoys upon the wheels of the waggons, in order to check the accelerated velocity occasioned by the excess of gravitating force. The steam-power would be useless in these descents from the same cause; but, after discharging a greater part of the steam, the engine might be allowed to work by the motion of its wheels, which would thus be restrained by the friction of the pistons in lieu of a brake.

A very small pressure applied by leverage to the brake would make the amount of friction equal to the force of gravity; and a power of 400lbs., which by means of the lever will be only 40lbs. at the hand, would effectually prevent the wheels from turning round, and cause them to slide along the rails for a distance of two or three feet, when the carriage would be entirely stopped. The convoys of all the carriages being secured at such a degree of pressure as would sufficiently counteract the gravitating force, and the velocity of the engine being checked by its friction, the whole train could be held back by the power of a man applied to the lever of the convoy attached to the hindermost carriage.

Thinking that a description of the locomotive steam-engine might not be unacceptable to the reader, I have abridged from the treatise of Mr. Wood, the substance of a few pages in which he describes very minutely one which is at present in use upon the Killingworth Railroad.

The Boiler is of malleable iron, cylindrical with hemispherical ends. A cylindrical tube passes through it within two inches of the bottom, in one end of which the fire is put and the other is terminated by a chimney. The grate is placed rather below the middle of the tube, and reaches about four feet within it; resting at the further end upon a narrow partition of brick. The boiler rests upon a square frame of malleable iron, supported by four steam-bearing cylinders seven inches in diameter, which are fastened on the frame by bolts with a joint perfectly steam tight.

The working cylinders are placed partly within the boiler, are of nine inches diameter, and lined on the inside with sheet copper. The piston rods work through stuffing boxes in the usual way and are attached to the cross-beams; sometimes formed of one piece and sometimes of more than one. The rectilinear motion of the piston-rods is secured by slides fastened to projecting arms cast upon the top of the cylinder, and kept perpendicular by braces. The connecting rods are fixed upon the cross-beams by ball-and-socket joints; and at the other end, by similar joints, to a pin fixed in one of the spokes of the engine-wheels, which serves the purpose of a crank; to strengthen this spoke a circular piece of metal attaches the two adjoining spokes with it.

The wheels are four feet diameter, made of cast iron, with circular naves rimmed out to fit the axle, and fastened to it by means of iron keys. The axles are of wrought iron, about 3½ inches in diameter, turned perfectly round at each end where the chair comes on; and also at the extreme end where they pass into the nave of the wheel. The chairs, on which the engine rests upon the axles, are of brass, 4 inches broad, and reach to the semicircumference of the axle. Two of them are fixed upon the frame of the carriage, and the other two are moved backwards and forwards, by means of a sliding groove, to keep the chain tight.

The steam is communicated from the boiler to the cylinder through a passage, the area of which is regulated by a sliding lever or handle which restricts the quantity, and thus regulates the velocity of the engine. The steam is admitted to each end of the piston by means of a sliding valve, which is moved up and down alternately, and which also opens a communication between the top or bottom of the cylinder and a pipe that turns up within the chimney, through which the steam escapes. The power with which it issues will be in proportion to its elasticity, and it will accelerate the velocity of the heated air accordingly. The sliding or steam-valve is opened and shut at the proper periods by means of an eccentric circular motion, effected by the axle and a lever attached to it; which causes another lever to move backwards and forwards as the axle turns round. This lever moves an arm which acts upon a third lever and a rod, by which the motion is communicated to the cross-head, and through it to the rod of the steam-valve.

The supply of water to the boiler is effected by means of a small forcing-pump fixed to the side, and worked by a rod attached to the cross-beam of the engine. Its diameter is very small, in order to prevent the temperature of the air from being too much reduced. No great quantity of water being required, it is pumped in at proper intervals, when the draught is easy and the requisite degree of pressure lower than common.

When the engine is travelling, the boiler is covered with thin deals, to prevent the too rapid abstraction of heat by the wind. The water and coals are carried in a convoy-carriage behind, to which carriage the loaded waggons are attached.

The endless chain which secures a uniform motion of the wheels, is formed of circular and flat links, and acts upon toothed wheels placed at the middle of each axle. The circular teeth fall between the teeth of the wheel, and the latter are inserted into the flat links of the chain; by which contrivance the friction is rendered comparatively trifling *.

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* See Wood's "Treatise on Railroads," from page 145 to page 151.

The largest engine used on the Killingworth railroad, has a boiler 9 feet long and 4 feet diameter, with a tube 22 inches in diameter. Weight, including a ton of water, about eight tons.

In one experiment upon three-feet wheels, this engine performed a distance of 26 miles with 36½ tons, in 6½ hours; consuming 13¾ cwt. of coal, and 490 gallons of water. And in another experiment upon four-feet wheels, it performed 9½ miles with 49 tons in an hour and a half; consuming 5 cwt. of coal, and 200 gallons of water. The ascent of the plane was very little, and the engine run both ways during the experiments. The average number of strokes per minute in the former case was 37 and in the latter 46; the difference in the velocity of the pistons being purposely occasioned by the management of the engineer.

Much has been said and written about the great rate at which these engines can be made to travel, but with very little foundation in truth. Their velocity is limited by several causes, viz. the small size of the boiler, and the area exposed to the action of the fire, which will only generate a certain quantity of steam; the velocity of the piston, which ought not to exceed 170 feet per minute with so small an expansive force; the length of the crank, which should not be less than 12 inches to give a sufficient leverage upon the wheels; and the diameter of the wheels which cannot conveniently or safely be more than four feet. The length of stroke of the pistons being twice the length of the cranks which turn the wheels, the longer the latter are made, the less will be the velocity of the engine, because the proper velocity of the pistons is confined to 170 feet per minute; and if a crank of 12 inches causes 85 strokes, one of 15 inches will only cause 68 strokes per minute. Then, since the wheels turn quite round with every *double* stroke of the pistons, there will be 8½ revolutions less per minute in the latter case than in the former.

Wheels of three-feet diameter are 3 and 1-7th yards in circumference; and the number of double strokes of the pistons, and revolutions of the wheels with a twelve-inch crank being 42½ per minute, the velocity of the engine will be 133½ yards per minute, or four miles and a half per hour.

Wheels of four-feet diameter are 4 and 1-5th yards in circumference; and under the same circumstances in other respects, the velocity of the engine will be 178½ yards per minute, or six miles an hour.

If larger than four-feet wheels were used, a longer crank would be required; and to obtain the same number of strokes per minute with the same effect, the engine must be made larger to increase the steam power. Then, as it would consequently be rendered much heavier, the rails should be proportionably stronger; and they ought to be set wider apart, owing to the centre of gravity being raised higher. Thus we see that the proper velocity of a locomotive engine upon the proposed line, with a load of 24 tons, cannot be made to exceed six miles an hour, without incurring a great additional expense; and to talk of a more rapid rate of motion than eight miles an hour, with an engine of moderate size when dragging a profitable load, is going quite beyond the bounds of reasonable calculation or useful application*. Even if a load of only 12 tons instead of 24 were attached to the engine, upon an inclination of 1 in 84, its rate of motion would not exceed eight miles an hour. In this case the velocity of the pistons must be 224 feet per minute, and the pressure of steam in the cylinders will consequently be less by 30 per cent. than with the proper velocity of 170 feet per minute. Then if we take into consideration the loss of power occasioned by the friction of the engine and its own gravity, we shall find that 12 tons, exclusive of the carriages, is a proper load when the rate of motion is to be eight miles an hour.

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* In a report or prospectus ascribed to Mr. Telford, upon the project of laying down a railway from London to Woolwich, the velocity of locomotive engines is stated to be *twice* that of the Woolwich stage coaches, which it is well known are driven at the rate of *nine miles an hour!*

See Quarterly Review, No. 63, *pages* 361—2.

The expence of a locomotive engine where coals are obtained at a low price, is estimated to be the same as that of three horses; but if it be equal to four, which I think is nearer the truth, there will yet be a considerable advantage in using the former as a motive power upon the proposed line of railway, instead of the latter; especially if we take into consideration the quicker rate at which these engines can travel. In the time that a horse would be employed to convey a load from the Sheffield Canal to the Peak Forest Railway, an engine would not only go, but would also return over the same distance with six times as great a weight; thus doing the *work* of *twelve* horses at an *expense* equal only to that of *four*. The advantage which they present with regard to economy is therefore *threefold,* whenever rapidity of conveyance becomes an important object.

This statement of the superior economy of locomotive engines over horse-power, may at first sight appear inconsistent with my preceding observations respecting the great expense attendant upon the use of *fixed* steam-engines. It should, however, be remembered that fixed engines in this instance will only be occasionally useful, while locomotive engines need never be out of employment, as their number can be proportioned to the quantity of traffic on the line. The stationary engines, to prevent delay, ought to have a power of steam sufficient to draw up the average load of a locomotive engine at once; though it may more frequently have only to draw up a single horse-load; and very often the preponderating gravity of the descending trade, will render the assistance of the stationary engine altogether superfluous. It is obvious, therefore, that in fixed engines a much greater expense would be incurred than in locomotive engines, compared with the useful effects which they would respectively produce; and it may be concluded that the former should never be adopted but from absolute necessity, in any line whereon the traffic is not expected to be very great.

Another objection to the use of fixed steam engines is the slow rate at which a load is moved up the planes, even with the possession of a high power; and we can only acquire a greater speed by iucurring a greater expence, or by losing in another way the time which has been so gained; for if we wish to double the velocity of the load, we must either be content to have it drawn up at twice, or else double the power of the engine.

There is still a further disadvantage arising from the adoption of this species of power; which is, an increase of distance. In many cases it will be necessary to turn out of the nearest line, in order to acquire that degree of inclination which is requisite for a fixed-engine plane; thus causing a loss of time in the conveyance of goods, and an increase of expense in forming and repairing the additional length of road.

Upon a review of all these considerations, I feel satisfied that it is better to give the railway a moderate general inclination, than to make use of so many fixed-engine planes as would be required in passing over this mountainous country; if those parts of the line lying between such planes are to be set out perfectly level.

Mr. Chapman, of Newcastle, in his report dated September, 1813, which I have already noticed, recommended the adoption of a railway up the Sheaf vale, in lieu of a canal, to join the line of the then-intended High Peak Junction Canal; and proposed to surmount the east moor by means of six inclined planes, three up and three down; each having an elevation of 200 feet perpendicular. For the use of these planes he considered steam-engines of 12 horse power to be eligible for the transit of 600 tons per day eastward, which quantity he calculated upon passing in the lime season. It appears to me that Mr. Chapman has much underrated the necessary power for this purpose; I shall therefore proceed to ascertain the full power which a fixed engine ought to possess, for drawing up a given weight in a given time; this being a problem which is easily solved when the height and inclination of the plane are known.

The friction of the ropes being very great in proportion to that of the carriages, when impelled by a stationary engine, this kind of power is far from being economical, in any case, upon planes which have but a small inclination; and if a high degree of inclination be adopted, when a weight of more than 30 tons is to be drawn up the plane at once, the expense of the necessary power would be too great in proportion to the useful effect produced; unless the traffic were so extensive as to keep the engine in constant employment.

When only locomotive engines are intended to be used upon the level parts of a railway, the inclination of 1 in 12 appears to be very proper for the fixed-engine planes, provided it is easily attainable; but when horses are to be the locomotive power, and each horse to take a separate load, an inclination of 1 in 6 will not be too steep. In this instance I propose that these two species of power should be used indiscriminately; and consequently recommend an inclination of 1 in 9 for the fixed engine planes.

With this inclination the highest steam engine plane in the proposed line will be 880 yards, or half a mile, in length; and my calculations of the necessary power for this plane shall embrace three different cases; first, supposing that the full average load of a locomotive engine is to be drawn up; secondly, the load of three horses, or half the load of an engine; and thirdly, only a single horse-load; the rate of motion in each case being three miles an hour.*

In the first case the load will be 32 tons, including the carriages; and I calculate the requisite power of the fixed steam-engine, for such a load, as follows:

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* The transit of a single horse-load at once, was probably what Mr. Chapman had in view when he decided upon engines of 12 horse power.

	lbs.
Gravity of the load 1-9th of its weight,	7965
Friction of the carriages 1-250th, ...	288
Friction of the rope 1-14th of its weight, (1000 yards of 7 in. circumference = 7000 lbs.)	500
Total Resistance	8753

and 8753 lbs. multiplied by 2640 feet gives 23107920 lbs. moved 1 foot in ten minutes, or 2310792 lbs. moved 1 foot in 1 minute.

Now a horse's power being estimated at 150 lbs. moving 2¼ miles in an hour, which is equal to 220 feet per minute, 150 multiplied by 220 gives 33,000 lbs. moved by a horse 1 foot in 1 minute. The power of the engine expressed in that of horses will, therefore, be 2310792 divided by 33,000, being equal to 70 horses. Or when, as in this instance, the exact rate of motion *per hour* is determined, we need only multiply the amount of resistance (8753 lbs.) by that rate (3 miles) and divide this product by the estimated power of a horse (150 lbs.) multiplied into its speed (2¼ miles;) the result will be the same.

In the second case the load will be 16 tons, including the carriages; therefore,

	lbs.
Gravity of the load will be	3983
Friction of the carriages	143
Friction of the rope	500
Total Resistance	4626

which is just equal to the power of 37 horses.

In the third case the load is only $5\frac{1}{3}$ tons, including the carriage; with which, the several resistances will be,

	lbs.
Gravity of the load	1327
Friction of the carriage	48
Friction of the rope	500
Total Resistance	1875

which would require a power of 15 horses.

It will be readily seen from these calculations, that the requisite power would be in direct proportion to the weight, if it were not for the friction of the rope; and as this resistance is the same with a small load as a great one, it would appear most advantageous to adopt a power adequate to the full load of a locomotive engine. But on the proposed line the traffic would not be extensive enough to keep in profitable employment stationary engines of 70-horse power. I think it will be better, therefore, to have a power equal to 37 horses, which is sufficient to take

3 horse-loads at once, and the load of a locomotive-engine at twice. Nearly the same power would be required upon a plane of 150 feet high as upon one of 250 feet with the same load; because the resistances would be the same in both cases, except that arising from the friction of the rope, which will be proportionate to its weight. The proportion of *one fourteenth*, which I have adopted, is the mean result of four experiments made on the Killingworth Railroad; in which there were 133 sheeves or rollers to bear up the rope, in the space of half a mile; the diameter of these sheeves being 11 inches, and that of their axles ¾ of an inch. The friction of the rope is materially affected by the ratio of the sheeves to their axles; and may, to a certain extent, be reduced by increasing the one and diminishing the other.

In addition to the power required to overcome the resistance occasioned by gravity and friction, a surplus of power is necessary for the purpose of generating the motion of the carriages at the proper velocity; instead, therefore, of 37-horse engines, we should have them of 38-horse power, to produce the desired effect.

Calculating the power of high-pressure engines by the length of stroke and rate of motion given to the piston, it is usual to deduct one fifth for the friction of all the moving parts of the engine, and to assume the power of a horse at 200 lbs., moving 2½ miles an hour, instead of 150 lbs. By this rule, a steam-engine of 38-horse power, with a pressure of steam in the boiler equal to 40 lbs. per square inch above the pressure of the atmosphere, ought to have a cylinder of 16½ inches diameter, and the piston should make 60 single strokes of 4 feet each per minute.

Notwithstanding the superiority of the expansive to the condensing principle, there is always a considerable loss of effect in high pressure engines, under the most favorable circumstances; which probably arises from the steam having a less expansive force upon the piston than it has in the boiler, whenever the motion becomes too rapid; and it is extremely difficult to manage the heat of the boiler so that the velocity of the piston shall always be such as to produce the greatest possible effect. It is for this reason that, in the construction of high-pressure engines the power of the horse is assumed at 200 instead of 150 lbs.; thus obtaining the same result in calculation as by assuming the pressure of the steam in the boiler at 30 lbs. per square inch, when it is actually 40 lbs.; or, which is the same thing, supposing that a pressure of 40 lbs. in the boiler, produces a force of only 30 lbs. upon the piston, owing to the loss of expansive force occasioned by the unequal motion of the piston itself.

I have assumed three miles an hour in these calculations as the proper rate of motion upon such planes, with engines of moderate power. If the velocity of the load be doubled, the power of the engine must be doubled also, or else the load should be divided in two. But I consider the rate of three miles an hour quick enough, because, after allowing for hindrances, it is equal to the usual and most advantageous speed of draught horses, viz. 2½ miles an hour; and in making use of horses we may safely calculate upon a load of four tons, exclusive of the carriage, being conveyed the whole length of the line at the same rate.

Although a loss of time will occur in passing these planes by dividing the load of a locomotive engine, it will be made up on the intervening parts of the line by the rapid rate at which those engines can travel. We may, therefore, reasonably expect that a load of 24 tons could be conveyed the whole length of the line in 4½ hours, which is at the rate of 5 miles an hour, including stoppages at the fixed engine planes.

I shall now proceed to form an estimate of the expense of making and keeping in repair the proposed line of railway, in the same general manner as I have estimated for the several proposed lines of canal.

It is stated in No. 62 of the Quarterly Review,* that the *actual average cost* of a number of railroads of different descriptions, comprising a length of 500 miles, is very nearly £4000 per mile, allowing them a double track. I cannot be far wrong, therefore, in taking this average for the foundation of my estimate; and I do not see occasion to add any thing on account of the superior manner in which this railway would be constructed, if carried into effect. Very little more labour than is common in such works would be required; except, perhaps, in preserving a more regular inclination by cutting and embankments; and this would be sufficiently counterbalanced by the low value of the land along the greater part of the line, and the abundance of stone, in this district, proper for blocks or sleepers to support the rails†.

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* Article 5, Page 349.

† The strength of the rails ought to be calculated for a pressure of two tons, although the actual pressure upon each wheel of the carriages will be only 1 and 1-3rd tons; and it will generally not be more than this upon each wheel of the locomotive engine, because one third of the engine's weight is taken off by the power of the steam-bearing cylinders.

For cast-iron rails I should recommend the dimensions and form following:—

Length 3 feet, breadth of upper surface 2¾ inches, tapering to ¾ of an inch in the middle, and swelling out at the bottom into a square of 1¼

The tunnels must, of course, be considered an addition to the expense, and should be taken at the same price per yard, according to their length, as is estimated for those in the proposed lines of canal; the requisite size of the openings and the strata through which they would pass being much the same.*

But the fixed-engines and machinery necessary for the inclined planes, being a part of the motive power, should be included along with the railroad waggons and locomotive-engines in the estimate of the expense of carriage; which ought to be considered separately from that of forming the line, as it is similar to the expense of providing boats and horses for a canal.

A general estimate for the proposed line of railway will then stand as follows:

22 miles of edge-railroad forming in
a superior manner, with a double

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inches; extreme depth in the middle of the rail, 6 inches, decreasing elliptically to 4 inches at each end. The mean depth of this rail being 5¼ inches and the mean thickness 1⅛ inches, its weight will be 56 lbs. per yard.

For malleable iron rails the following dimensions will be proper, with supports 3 feet asunder:—breadth of upper surface 3 inches, mean thickness one inch, and the depth 4 inches throughout. Its weight will consequently be about 40 lbs. per yard. This kind of rail is easily manufactured by means of rollers.

* I have been informed that the tunnel near Buxton, in the Peak Forest and Cromford line of railway, was contracted for at the price of £10. per lineal yard. The strata through which it passes are gritstone and shale.

track, at £4000 per mile, including every expense except the tunnels and motive power, ...	88,000
Tunnel 1¾ miles long at £13. 10s. per lineal yard, ...	41,580
Do. half a mile in length at £11. per lineal yard, ...	9,680
A branch railway to the Castleton Road, near Brough, ...	10,740
Total	£ 150,000

This amount is only £12,000 more than *one third* of Mr. Telford's estimate for the Penistone line of canal, and it is full £207,000 less than the least expensive of the lines through Edale. Consequently, if the annual repairs of the proposed railway would not cost more per mile than those of the proposed canals, an income of £12,500 per annum would pay the subscribers to the railway, as well as £37,772 would pay upon the Penistone line, and £27,395 upon the Edale line, No. 3.*

If, therefore, the probable annual income cannot be estimated with certainty at more than £20,000 per annum upon any of the projected lines, subscribers to a railway would stand a good chance of getting 10 per cent.

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* See Page 32.

for their money, and may be quite sure of 5 per cent., while the subscribers to the Penistone line of canal must be content with a profit of less than 1 per cent.

It is stated in the report of the Committee for the proposed Sheffield and Manchester Junction Canal, that the repairs of the Peak Forest Canal during a period of 30 years have cost only two thirds as much as those of the railway connected with it; but in giving this statement it ought to have been added, that this railway is a *tram-road* of a very inferior construction. An *edge-railway* of wrought iron, being laid at first with the utmost nicety in lengths of 15 feet, supported at the distance of every yard by strong blocks of stone, firmly bedded and accurately adjusted, will present so little obstruction to the carriages, especially if their wheels be large, that it will remain for a long time free from injury; and if proper care be taken to adjust or replace such as become dislodged, bent, or broken, as soon as the accident occurs, the annual expense of repairs must be trifling indeed, compared with that of the inferior tram-road belonging to the Peak Forest Canal Company.*

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* Should the proposed line of Railway from Sheffield be carried into effect, the Peak Forest Canal Company will no doubt take up their road and replace it with an edge-railway of the same kind as would be adopted on the new line. But if this should not be done, it will be necessary to

Instead, therefore, of estimating the expense of repairing a railway compared with that of a canal, to be as 60 to 40, which we are led to suppose from the report on the Penistone Line, I should consider the ratio to be only as 40 to 60; but rather than incur the imputation of leading any one into error by exaggeration, I will in this respect presume that they are equal to each other.

The estimated cost of the proposed railway, exclusive of the tunnels, is about £100,000; and taking the repairs at 5 per cent. per annum, they will amount to £5000; which with 5 per cent. upon the Capital for the subscriber's profit, makes the requisite annual income £12,500. But this is not sufficient if we take into consideration the loss of interest during the progress of the work; the risk attending all speculations of this nature, with the subsequent expences of collecting the tolls and managing the concern; to cover all which, we must take an additional 1 per cent. upon the capital; thereby increasing the amount of revenue, which ought with certainty to be received, to £14,000 per annum.

Pursuing the same mode of calculation

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continue the new line, parallel with the old tram-road, a distance of two miles beyond Chapel-Milton, till it comes in contact with the basin of the Peak Forest Canal at Bugsworth.

with regard to the several proposed lines of canal, the smallest revenue which should arise from each of them to clear the common rate of interest to the subscribers, will be as follows:—

	£
Peniston line	41,880
Castleton line	36,597
Edale line, No. 1	31,620
Do. No. 2	33,112
Do. No. 3	30,969
against which I will place, the proposed Railway	14,000

Then, supposing it possible to obtain £41,880 per annum upon any of these lines, the clear interest upon each would be

on the Penistone line	5	per cent.
.... Castleton line	6⅒	—
.... Edale line, No. 1	7½	—
.... Do. No. 2	7	—
.... Do. No. 3	8	—
.... Railway	23½	—

But if it should happen that no more than £14,000 per annum can be collected upon any line, the clear annual profit of the subscribers to the railway will be full £5 per cent. while that of the subscribers to the Castleton or Edale lines will scarcely exceed six shillings and eight pence per hundred pounds, and on the Penistone line the expense of repairs, with the additional one per cent. would *exceed their income* by £7340.

The expense of managing the concerns of a canal would certainly not be so great, in proportion to the capital invested, as in a railway; but, on the other hand, the speculative risk would be far greater, in this instance; because more than a double, and on one line even a *treble* income, would be required to clear the lowest rate of interest which ought to be expected from such investments. The loss of interest during the progress of the work would also be greater; for it would be full *nine years* before a canal would be brought into operation, while the railway might be completed in three years. Upon the whole, therefore, I am fully justified in reckoning the same per centage upon the capital as a proper return on these accounts, in the several proposed lines of canal, as I have done in calculating the income which ought to arise upon the proposed line of railway.

As I have before observed it is necessary to make minute enquiries in order to arrive at a correct estimate of the traffic which would be carried on through any new line of railway or canal; and this part of the subject would certainly, as Mr. Telford has observed, be most properly investigated by those connected with the manufacturing and commercial interests of the country; nevertheless, I may be allowed perhaps, after stating the opinions of others, to hazard a conjecture of my own.

Mr. Chapman was of opinion that, if a canal were opened between Sheffield and the Derbyshire limestone district, the annual amount of the traffic in that article alone would be 60,000 tons; but this was perhaps only a rough guess. Mr. Hazlehurst estimates it at 80,000 tons; and that of coals at 30,000 on the Sheffield part of his line. Whether his calculations on this head have a better foundation than Mr. Chapman's I cannot say; but from want of more accurate information, am inclined to adopt them, feeling satisfied that they have not been made on too high a scale. General merchandize, corn, flour, and malt, Mr. Hazlehurst has calculated at 45,000 tons; and ashlar-stone, mill-stones, slate and paviours, at 10,000 tons per annum.

Perhaps I shall not be far from the mark if I say 400 tons per day going 14 miles, (that is, 11 miles upon the main line, and 3 upon the branch;) and 200 tons per day going the whole length of 22 miles. For the former only one penny per ton, per mile, should be reckoned; as the traffic would consist principally of mineral productions; but for the latter, two pence per ton, per mile, will not be too much. There would be other smaller sources of revenue; but these I think it is as well not to take into account, for it is better that the actual receipt should exceed the estimate rather than fall short of it.

My calculation of the annual income to arise upon the proposed line of railway will, therefore, stand thus:—

	£	*s.*	*d.*
400 tons, 14 miles at one penny....	23	6	8
200 tons, 22 miles at twopence	36	13	4
Amount per diem £	60	0	0

and as there are about 310 working days in the year, it would amount to £18,600 per annum.

The question next to be considered is, whether the expense of conveying goods upon the railway, exclusive of the tolls, will be greater or less than the freightage upon the Penistone line of canal*; and upon this point I have ascertained that it is nearly the same on the one as the other when horses are used upon the railway, but greatly in favour of the latter when steam-engines are made the locomotive power. The following are my calculations on this part of the subject.

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* I select the Penistone line for a comparison, because it has been placed in a more conspicuous light than the other lines, and is in progress of being carried into effect, provided sufficient money can be raised for that purpose.

The cost of a 20 ton boat will be about £200, and a carriage proper for the conveyance of 4 tons upon a railway would cost about £40; the first expense of boats is, therefore, equal to that of the railroad waggons.

But each boat requires only one horse while 5 four-ton waggons require 5 horses; and taking the value of each at £20, the first cost of a boat and horse will be £220, and that of 5 waggons and horses £300.

The expense of attendance will be precisely the same on both kinds of conveyance; for a boat will require two men to navigate it and a boy to attend the horse, and every railroad waggon must be attended by a boy, or a man for every two waggons. I reckon the expense of a boy at half that of a man.

Then, calculating the expense of repairing and renewing the boats and waggons, with interest on the purchase money, at 20 per cent. on the first cost; and the decrease in the value of horses, with hazard of loss and interest, at the same rate; the keep of a horse, rent of stabling, harness and shoeing, being £36 per annum, a man's wages £40 and a boy's £20, I find the annual expense of working a canal boat of 20 tons, exclusive of the dues, is £180 and that of running five waggons containing 20 tons upon a railway by means of horse power, is £340.

I come now to a comparison of the *annual performance* of a canal boat upon the Penistone line with that of five waggons on the proposed railway, by which means we can ascertain the price of carriage, by either mode of conveyance, per ton, per mile.

The number of miles in the Penistone line is 39¼, which, on account of the numerous locks, will require four days for the passage of a boat, being about ten miles per day, or 3100 miles per annum. This amount multiplied by 20 gives 62,000 tons, conveyed one mile in a year at an expense of £180; and if we add 30 per cent. for the carrier's profit, the cost of carriage upon this line will be nearly one penny per ton, per mile.

Upon the railway the waggons would go the whole length of 22 miles in one day, which is equal to 6820 miles in a year; and this number multiplied by 20 gives 136400 tons carried one mile in a year at an expense of £340, and with a profit of 30 per cent.

added, it will amount to £442 or three farthings per ton, per mile.

But to this expense there should be added the charges attendant on the use of the five fixed-engine planes; four of which would be supported by the transit of 600 tons per day or 186,000 per annum; and the fifth by 200 tons per day or 62,000 per annum.

Then, estimating the annual cost of a steam-engine of 38 horse power with machinery for an inclined plane, (including interest, repairs, renewals, fuel, a tenter's wages, and the profit of 30 per cent.) at 650*l.* per annum, it will be found that the expense per ton will be five-pence-halfpenny upon the whole line, or one farthing per ton, per mile; and this added to the charge for the horse conveyance makes the total charge for carriage upon the proposed line of railway nearly the same as on the Penistone line of Canal, viz. one penny per ton, per mile. In making this calculation I consider the engines to be worked only half the time, one day with another, and estimate for fuel accordingly; and I make a still greater abatement in the fifth engine with regard to fuel, as it would have so much less to do than the other four.

A locomotive engine like the one I have

described, with its carriage, will cost 400*l.* and the annual expense of repairs with interest and decrease of value, may be taken at 20 per cent., or 80*l.* The coal consumed will be about 16 cwt. per day, say 100*l.* a-year. Attendance of one man and a boy will be 60*l.* per annum; and the 20 per cent. for interest and repairs of six waggons is 48*l.* per annum, being altogether including a profit of 30 per cent., 375*l.*

Then, as the engine will perform two journies in one day, the number of miles it will travel in a year is 13,640; and this being multiplied by 24 gives 327,360, the number of tons conveyed one mile in a year at the expense of 375*l.* which is very little more than one farthing per ton, per mile; and as the company of proprietors would probably themselves undertake the carriage by these engines, a less profit than 30 per cent. may be allowed, so as to reduce the charge to one farthing per ton exactly. Adding to this the charge for passing the fixed-engine planes, it does not amount to more than a halfpenny per ton, per mile; being only half the expense of conveyance on the line of the proposed Sheffield and Manchester Junction Canal*.

*** By the use of locomotive engines a great saving would be effected in the repairs of the horse path, which would not have to be so frequently renewed.**

In drawing a comparison between the two, it should not be forgotten that by the line of railway the distance to Manchester is 3½ miles shorter than by the proposed canal; and that in the latter there is a mile of land carriage from the Sheffield Canal-basin, the expense of which would alone amount to a halfpenny per ton, per mile, upon the whole length of the line.

If the Penistone line were altogether an open canal, there is no doubt that it would be superior to a railway for the conveyance of a great quantity of heavy goods at a slow rate of motion; but its numerous locks will materially increase the expense, and prove a very serious impediment to the navigation. In a level country where the traffic is extensive, a canal will always compete successfully with a railway at the common speed of a draught horse; but in a mountainous district it would have no chance whatever; and those who feel inclined to speculate in such a scheme had better look before they leap.

For the conveyance of valuable goods at a velocity of 5 or 6 miles an hour, a railway will, under any circumstances, be superior to a canal; because the resistance of water increases as the *square* of the velocity, and the mechanical force must consequently be increased in proportion to the *cube* of the velocity. For instance; if a horse can draw a given load upon a railway at the rate of 2½ miles an hour, two horses can draw the same load at the rate of 5 miles, and four horses at the rate of 10 miles an hour; but on a canal, a weight sufficient for one horse at the rate of 2½ miles an hour, will require eight horses at a velocity of 5 miles, and no less a number than 64 horses at the rate of 10 miles an hour.

On narrow canals the resistance is still greater than on wide ones, the difference being one fifth in favour of the latter; but a quick motion should always be avoided on narrow canals, on account of the great injury it would occasion to the banks.

It has been often and very justly urged against canals on a high level, that they are liable to frequent stoppages from frost; and the gentlemen of the committee for carrying forward the Penistone line have noticed this objection in their report; stating at the same time, that, on an average of 30 years, the trade on the Peak Forest Canal which is the highest in the kingdom, had not been stopped from this cause more than 10 days per annum. The summit-level of the Penistone line is, however, between four and five hundred feet higher; and it is not very easy to calculate, at that great elevation, how many days the proposed canal may be dry in the summer or frozen in the winter. Experience only can determine this point, since no precedent applicable to the case can be found either at home or abroad.

In answer to the objection to high canals on the score of frost, it may be urged that railways are sometimes rendered impassable by snow; but I would reply, that it frequently freezes when it does not snow, and the fall must be very heavy to impede the passage of carriages upon an *edge* railway; besides, the surface of the rails may be generally kept uncovered by the timely use of some contrivance attached to the front of a locomotive-engine.

Another advantage which railways have over canals, I must not omit to mention; and that is, the facility with which repairs can be effected on the former without any hindrance to the traffic; while on canals it is frequently necessary to draw off the water for this purpose; thus putting a stop to business on a part of the line until the requisite repairs are completed.

Having now in some measure shewn the superiority of a well-constructed edge-railway for passing over a mountainous district, I will repeat this plain question: would it be prudent to expend so large a sum as £420,000 in the construction of a narrow canal, impeded by numerous locks and at a great distance from the Derbyshire limestone district, or even £350,000 with fewer locks and approaching very near to the limestone, when a railway such as I have described can be executed in one third of the time for £150,000, and would present every possible advantage to the public?

Supposing this railway were actually in operation; lime could be delivered at Wortley by land carriage from Sheffield as cheap as it could be obtained from Bugsworth by the proposed Sheffield and Manchester Junction Canal; and if a portion of the many thousands of pounds which would be saved by adopting the railway in preference to a canal, were expended in the formation of a similar railway up the valley of the Dun to the distance of sixteen miles from Sheffield, lime might be had even at that distance, as cheap as it could be obtained from Bugsworth. And if another portion of the saving were expended in making a branch from the proposed line near Moscar House to Bradfield, the same article could be had there for less than half the price which it would cost if brought along the Penistone line. It appears, therefore, rather absurd to make this very expensive canal, for the sake of getting lime upon the lands adjoining the valley of the Dun, but perhaps this is a minor consideration.

In addition to the advantages which I have already pointed out, the proposed railway would be productive of still greater benefit to the public, as well as profit to the subscribers, if it were continued a mile beyond Bugsworth to the Peak Forest and Cromford Railway at Whaley Bridge; and if both were formed on the same plan, carriages might pass from one line to the other.

Thus a ready communication from Shef field would be opened with the midland counties and the south of England, as well as with Manchester and Liverpool. The distance to Cromford would be no more than 55 miles, which could be passed over by a loaded horse, at the common speed, in two days and a half; five miles of the ground being occupied by steam-engine planes. If we include the seven miles of canal from Cromford to Buckland Hollow, we need allow no more than three days to reach the latter point; and by the Grand Commercial line of Canal, it would have occupied 34 hours according to Mr. Dean's plan, and 26 hours by Mr. Hazlehurst's.*

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* See Hazlehurst's Second Report, Pages 17 and 68.

Taking, therefore, the mean of these two estimates of time, and assuming 10 hours for a day's work, it would have required no less than three days to go from Sheffield to Buckland Hollow by the projected canal. Consequently the *time* being the same, the *distance* may, in effect, be considered so too. And if locomotive engines were used instead of horses, the railroads would be *nearer* than the canal by *half the time.* Besides this advantage, the Peak Forest and Cromford Railway being generally level between the fixed-engine planes, twice as great a load can be drawn upon it as upon the proposed railway from Sheffield. On the former, a horse will take 8 tons, and a locomotive-engine 50 tons, exclusive of the carriages; so that taking an average of the whole line from Sheffield to Cromford, three horses would convey the burden of a narrow-canal boat; and a single locomotive-engine that of *two* boats.

This idea of a junction with the Cromford Railroad causes me to take a fresh view of the subject, and I am strongly inclined to recommend the extension of the line to Whaley, instead of stopping it at Chapel-Milton or at Bugsworth. In that case, the maximum inclination of the proposed railway may be reduced from 1 in 84, to 1 in 115, as we shall not be compelled to coincide with the Peak Forest Railway, but may take an entirely new line from the tunnel at Cowburn Ridge to Bugsworth; and we may reduce the inclination to 1 in 115 (or 5-16ths of an inch per yard) by means of a longer fixed-engine plane.

With this inclination throughout the line, there would be three such planes, together 615 feet in height, between Sheffield and the first summit; two between the first summit and the river Derwent, 440 feet high; and one of 220 feet between the second summit and the canal at Bugsworth; making a total of 1275 feet perpendicular in 6 planes, instead of 1050 feet in 5 planes which would be required if the inclination between those planes were allowed to be as steep as 1 in 84. The ascent from the Derwent to the second summit at Cowburn Ridge can be accomplished by a gradual rise of 1 in 115 without the aid of a fixed-engine plane.

The additional expense in fixed steam engines will be more than counterbalanced by the saving in locomotive power; as a horse will be able to ascend an inclination of 1 in 115 with a load of 5 tons, and a locomotive engine with 30 tons, exclusive of the carriages. But if a less degree of inclination than this were resorted to, the expense of the additional number of fixed engines would exceed the saving of locomotive power.

The extra length of three miles would not cost more than £10,000; so that if only 30 tons per day were added to the traffic in consequence of this extension of the line to the Cromford Railway, the subscribers would clear 5 per cent. per annum upon the first cost, and if 50 tons per day were added, they would clear 11 per cent. (upon the £10,000) over and above the annual expences.

Should it be found difficult in the present state of commercial affairs to raise so large a sum as £160,000 upon a speculative undertaking, though this can scarcely be considered such, the railway may be constructed for the use of horse-power only (in conjunction with the fixed-steam-engines) upon a scale which would reduce the expence £1000 per mile, and that of the tunnels £10,000 in the aggregate. The total amount of the first cost would then be only £122,000 for a length of 25 miles from the Sheffield Canal to Whaley, and the branch of 3 miles from Cock's Bridge to Brough Lane-head.

The locomotive steam-engine being a great weight, it is necessary to have the rails made proportionably strong, in order to support it without deflexion; or, if they be cast iron, to avoid the risk of fracture by percussion; I therefore considered it the best plan to put the load of a horse into one carriage, the pressure of the whole upon the rails being still less than that of the engine. But if locomotive engines are *not* intended to be used, the load of a horse may be divided between two carriages of a proportionate weight; and in the latter case the rails need be only half the strength which would be necessary in the former. The axles may also be reduced from 3½ to 2½ inches diameter, and with this size 3 feet wheels would cause less friction than 4 feet wheels with axles of the other size. Then, as the center of gravity in the load would be lower, the rails need not be so wide apart, and a less quantity of land would be required; the tunnels would also be as convenient if only 18 feet wide, as in the other case with a width of 22 feet, and their height might likewise be proportionably reduced.

Having now said as much as can well be comprised in the short space of a pamphlet, I will leave the subject to the further consideration of the public; and if, upon due investigation, the measure which I advocate be found most eligible for the general interest of the community at large, I have little doubt but that it will be carried into effect with less difficulty than was experienced in the accomplishment of that very useful public work, the Sheffield and Tinsley Canal; and certainly with a much better prospect of a quick and profitable return.

ERRATUM.

Page 12, line 11, for 100, read 70.

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